Consequence of the brighter-fatter effect for gain measurement

(Linear fit of PTC => quadratic fit)

We have shown that the brighter-fatter effect can be explained by electrostatic distortions within pixels due to charges collection, as a consequence :

=> The perturbation exactly conserves charges.

=> The integral of the correlation function in flatfields is conserved.

=> In actual PTCs, the poisson variance is recovered by adding covariances to variance.

=> The gains of a read out channels are more accurately evaluated from second degree polynomial fit on the actual PTC than with linear fit of raw PTC, or rebin images, or re-summing covariances.

The integral of the correlation function in flatfields is conserved

We assume that the observed flatfields are a perturbed realization of ideal flatfields which would have independent pixels in the absence of perturbation.

Perturbation : $$Q'_{ij} = Q_{ij} + \delta Q_{ij}$$

Covariance k,l of observed flatfield : $$C_{kl} \equiv \frac{1}{N} \sum_{ij} Q'_{i,j} Q'_{i+k,j+l} - \mu^2$$

$$\sum_{kl} C_{kl} = \frac{1}{N} \sum_{kl} \sum_{ij} Q'_{i,j} Q'_{i+k,j+l} - \mu^2$$

$$= Var(Q) + \frac{2}{N} \sum_{kl} \sum_{ij} \delta Q_{i,j} Q_{i+k,j+l} + O(\delta Q^2)$$

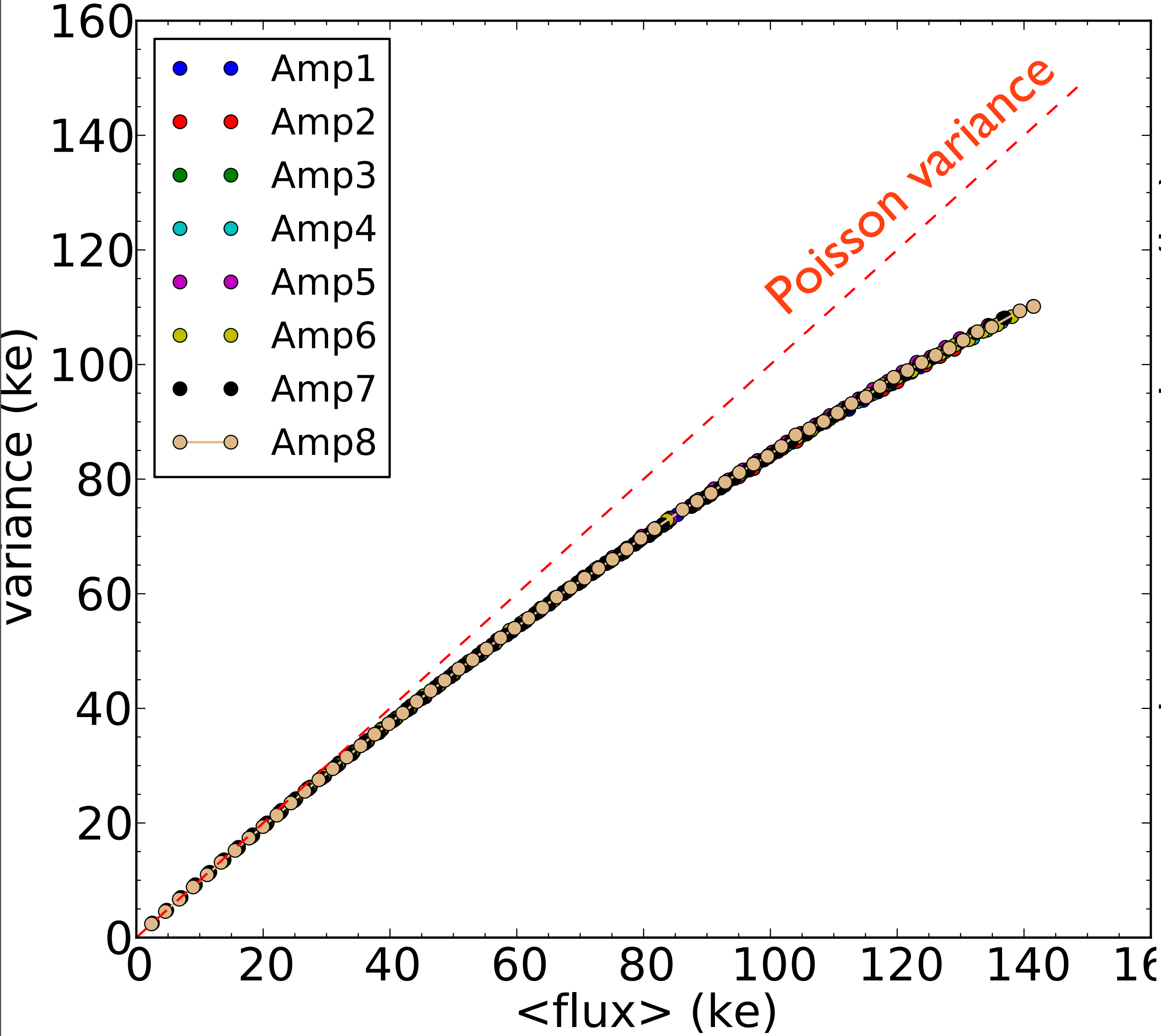
Integral of correlation function : $$= Var(Q) + \frac{2}{N} \sum_{ij} \delta Q_{i,j} \sum_{kl} Q_{k,l} + O(\delta Q^2)$$

Charges conservation : $$\sum_{ij} \delta Q_{i,j} \equiv 0$$

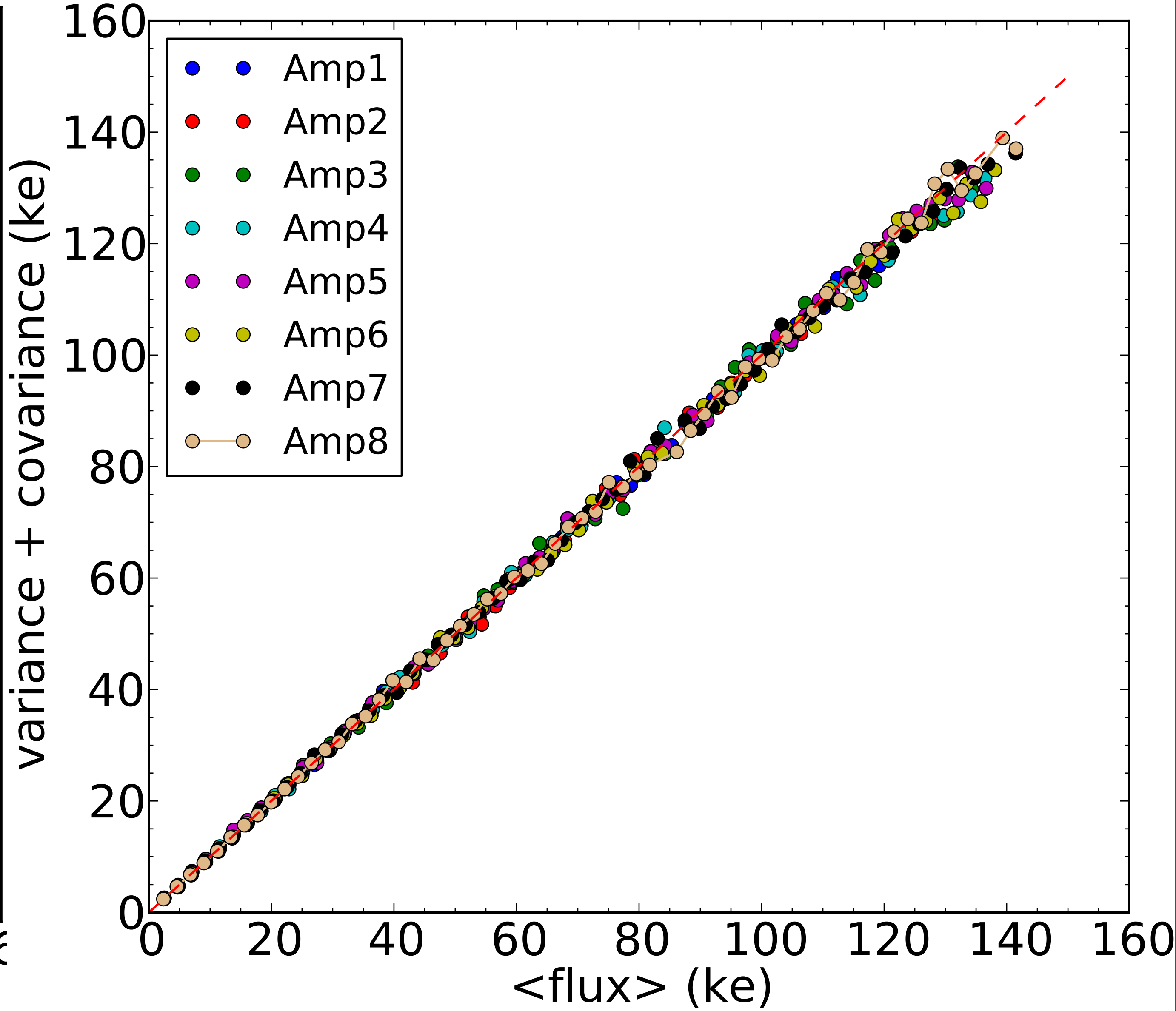
(1) So : $$\boxed{\sum_{kl} C_{kl} = V(Q)}$$

This allows one to recover the Poisson variance by summing all correlations

actual PTCs



PTCs+cov recover the Poisson variance



Linear fit leads to gain overestimation

Relation between rebinning images and summing covariances :

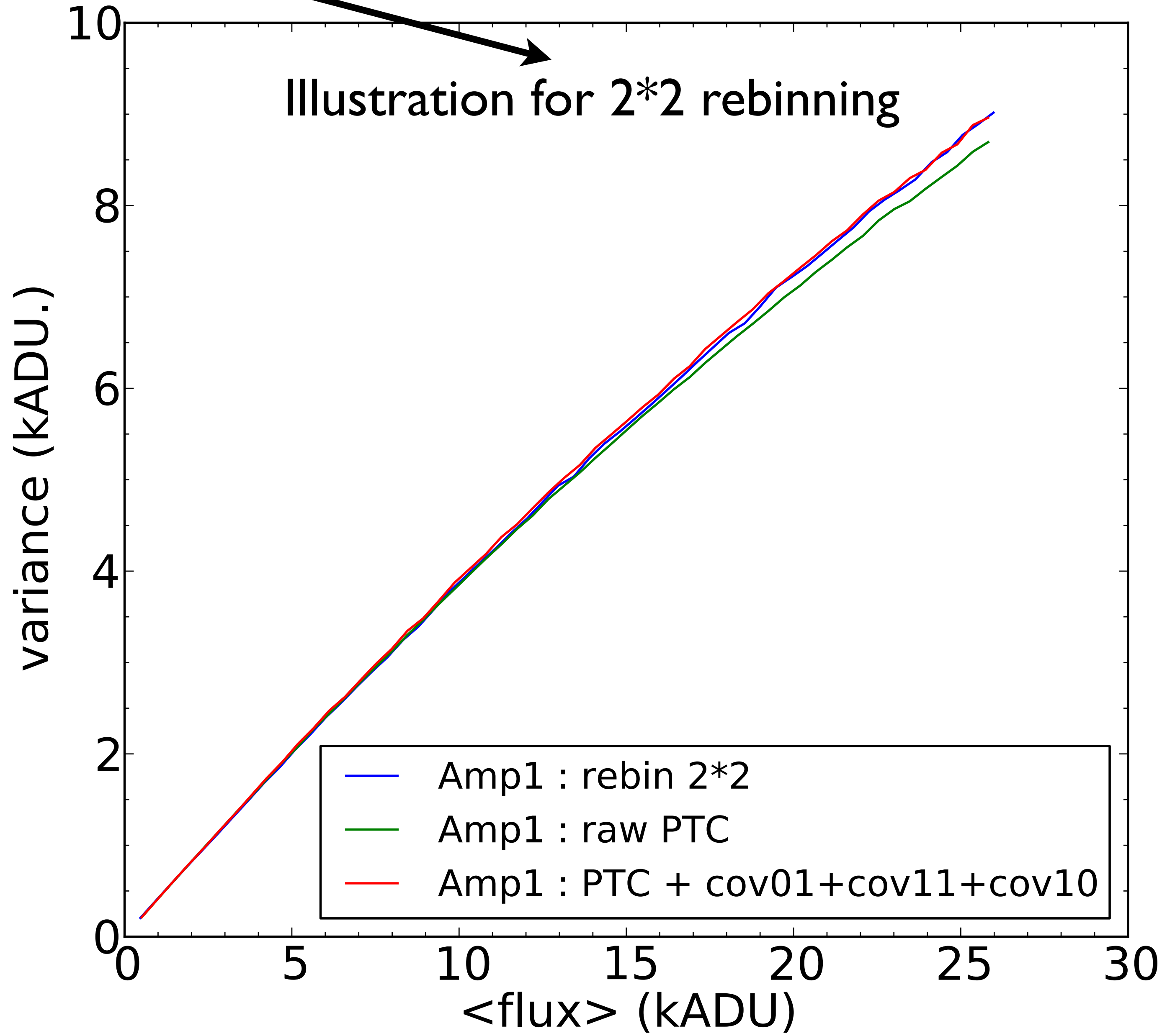
$$V_{rebin}\Big((k\times l) < N_{ADU} > \Big) = (k\times l)\Big(V_{actual}(< N_{ADU} >) + \sum_{k\neq 0, l\neq 0} C_{kl}\Big)$$

Rebin images miss half the covariances

Gain overestimation :

- Linear fit of low range Raw PTC : many %
- Linear fit of binned pixels (5*5) : 1-2%
- Linear fit of Variance + cov(+/- 4 pix) : 0.5%

  (see extra-slide)



Gain measurement on actual PTCs

Poisson noise : $$V(Q) = \frac{1}{G} N_{ADU}$$

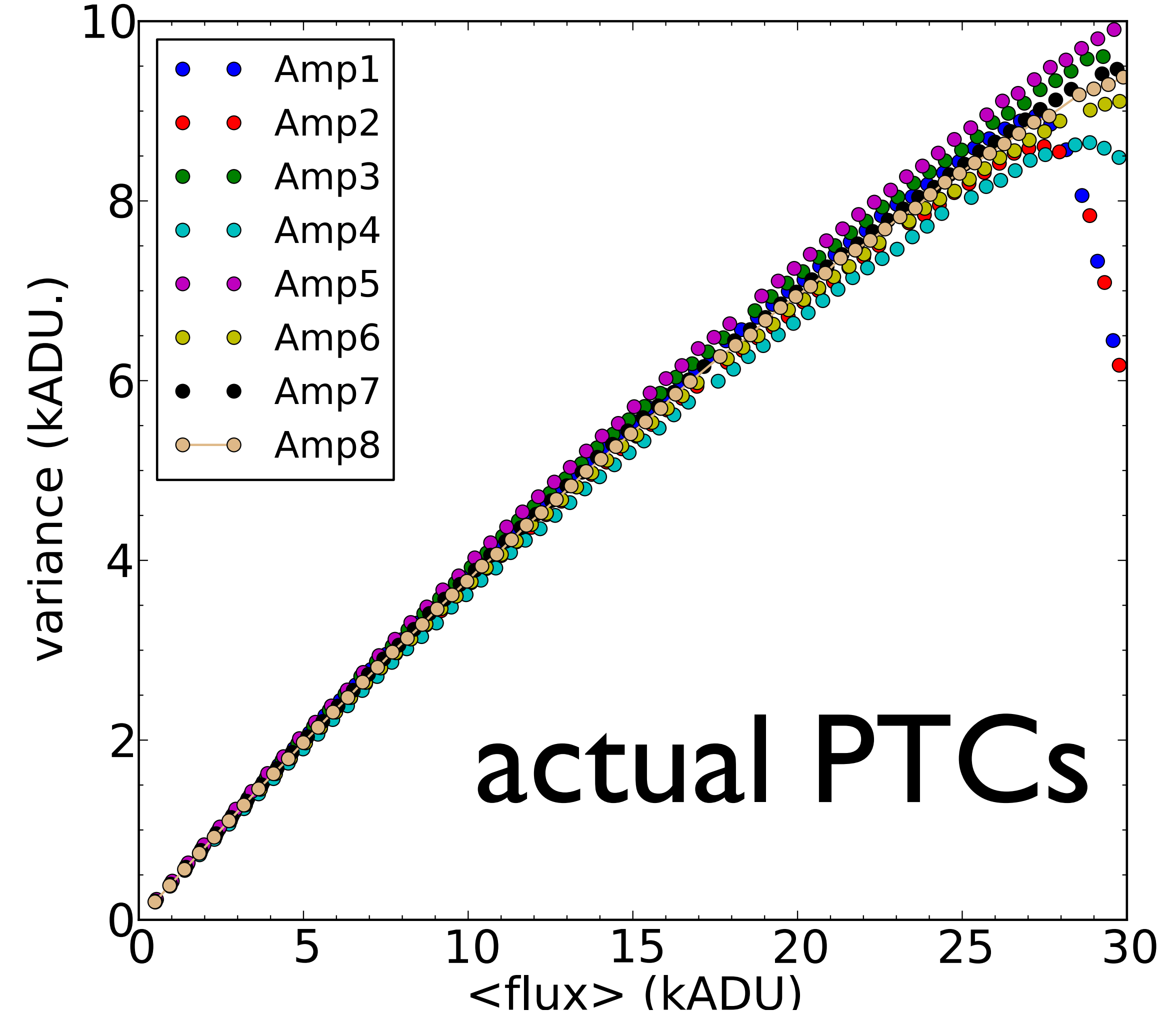
so, using (1) : $$\frac{1}{G} N_{ADU} = \sum_{kl} C_{kl}$$

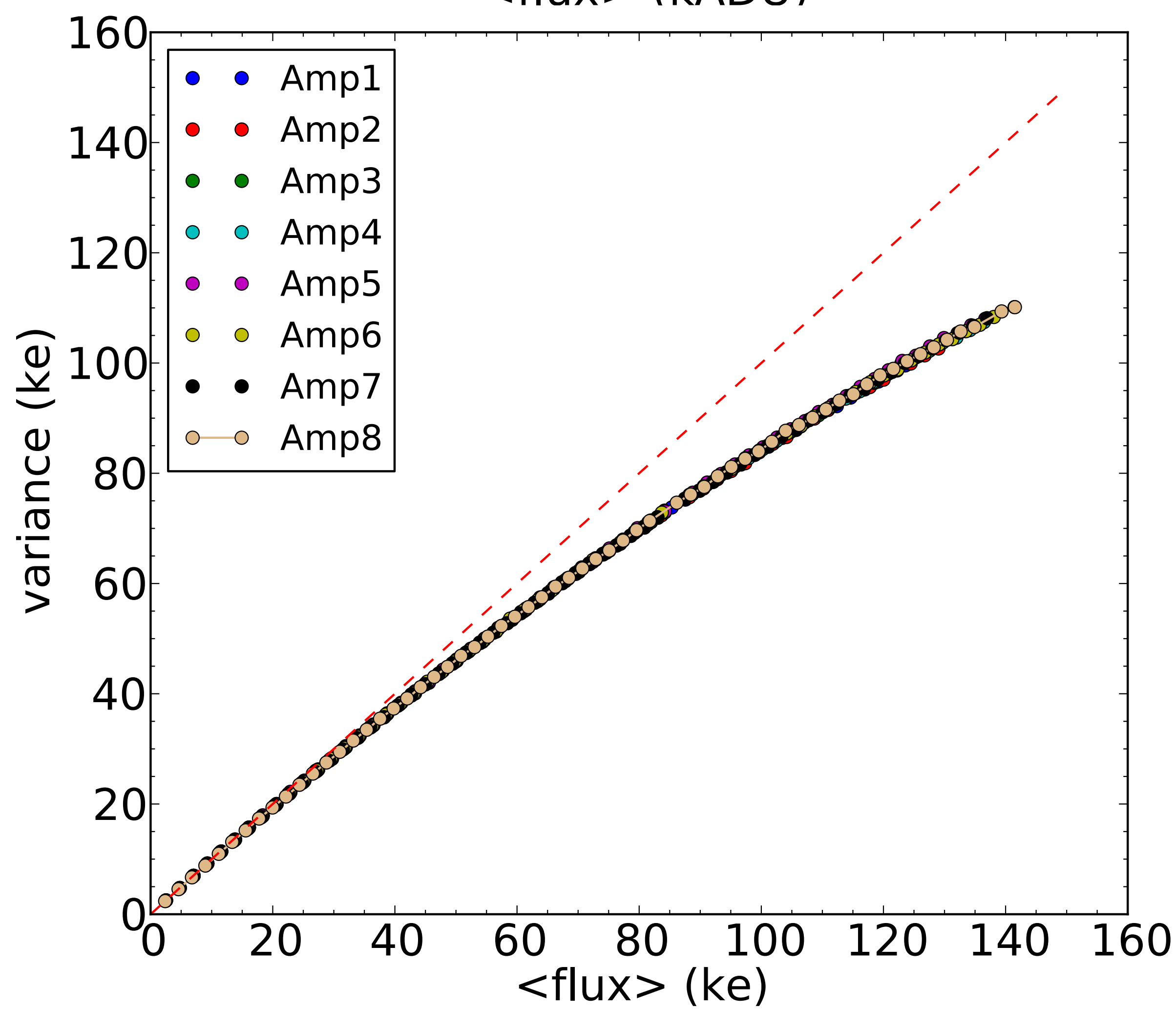
$\sum_{kl} C_{kl}$ is the combination of the variance and the covariances:

$$\sum_{kl} C_{kl} = V_{actual}(N_{ADU}) + \sum_{k \neq 0, l \neq 0} C_{kl}(N_{ADU}^2)$$

Given the electrostatic hypothesis, the C_{kl} scale quadratically with the flux, therefore :

$$V_{actual}(N_{ADU}) = \alpha N_{ADU}^2 + \frac{1}{G} N_{ADU}$$





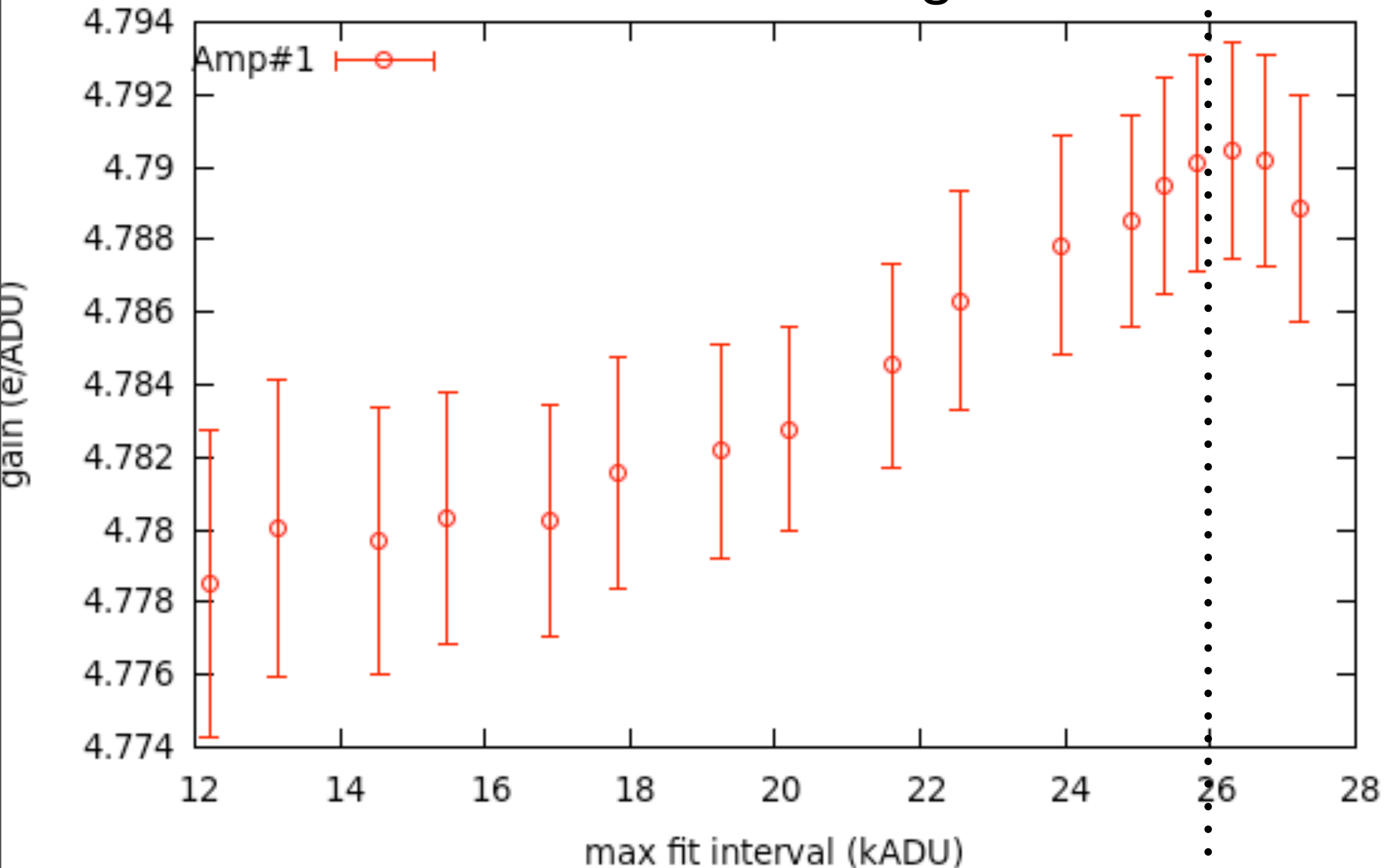
Result of the quadratic fit

With ≃1Mpix. segment and ≃ 50 pair images => 0.2% relative uncertainty

+ 0.2% dispersion of the gain on the interval below PTC extremum

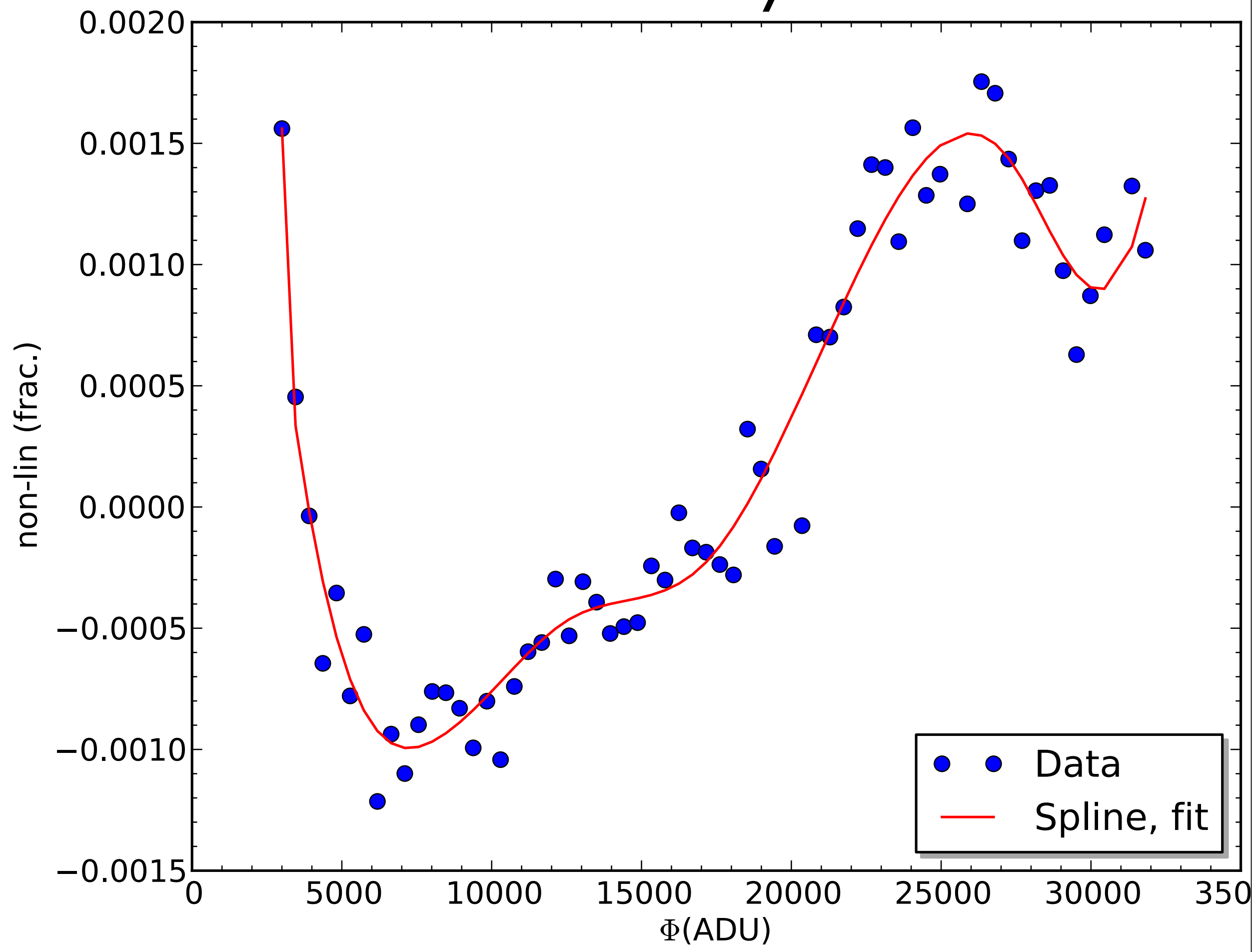
Variation of the gain : non-linearity of CCD response ?

Gain estimation Vs fitting interval



Reduce chi-squared = 1 below 26kADU

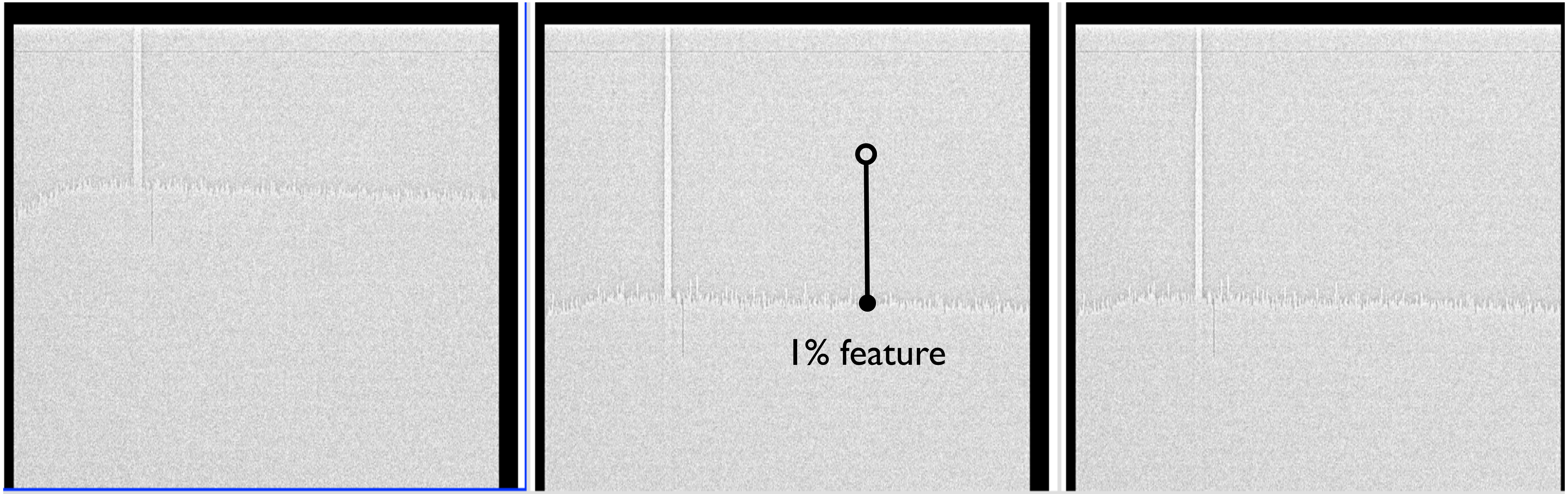
non linearity residuals



extra slides

Masking faint tearing effects

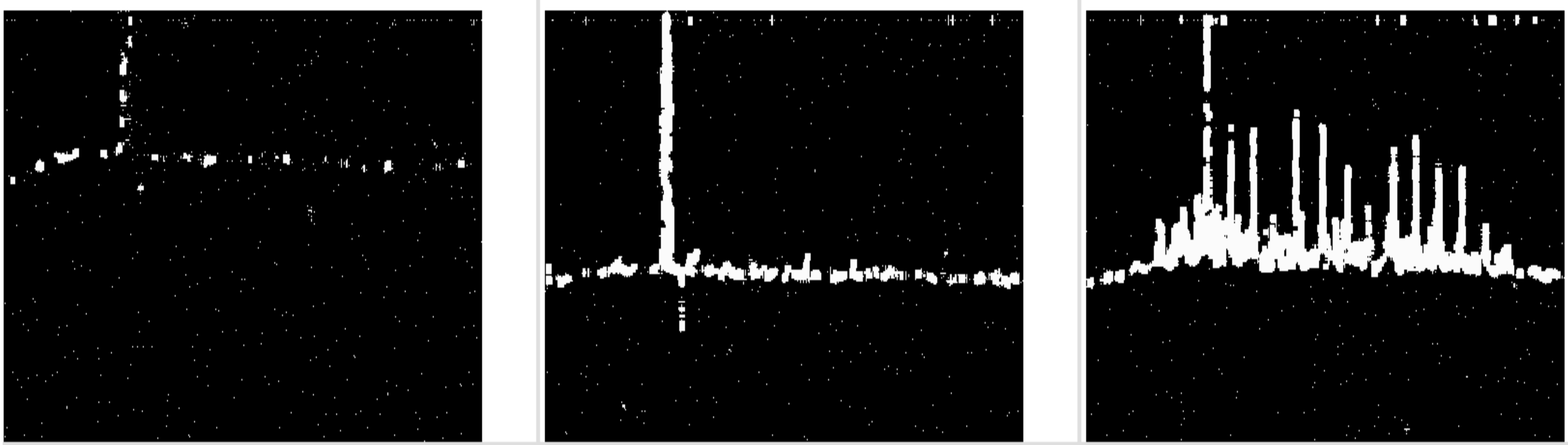
P. Doherty Data, CCD E2V 112-03 ; ExpTime = 5s. ; BSS = -70 V

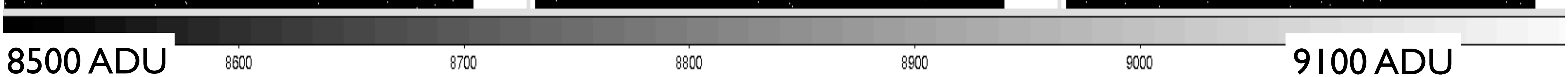


CV=8v Reject. pix.=11 621

CV=9v Reject. pix.=19 053

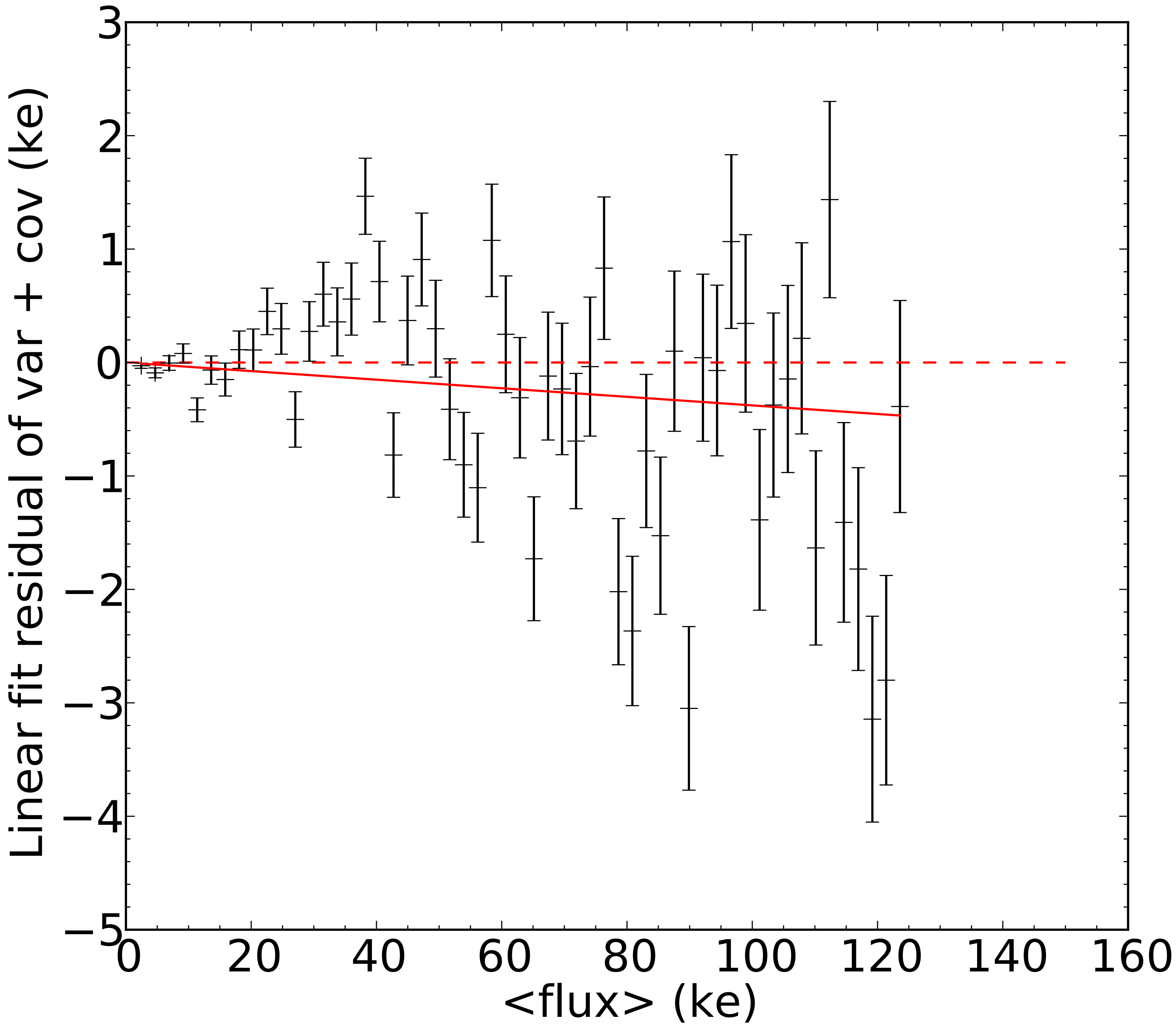
CV=10v Reject. pix.=34 544





Linear fit of Variance + covariances up to +/- 4pixels :

=> It overestimates the gain by about 0.5%



slope1, sslope1 = 0.9962 +/- 0.0021
slope2, sslope2 = 0.9906 +/- 0.0021
slope3, sslope3 = 0.9951 +/- 0.0030
slope4, sslope4 = 0.9962 +/- 0.0027
slope5, sslope5 = 0.9986 +/- 0.0027
slope6, sslope6 = 0.9902 +/- 0.0023
slope7, sslope7 = 0.9950 +/- 0.0022
slope8, sslope8 = 0.9970 +/- 0.0021

Gain Vs Backside substrate voltage